represents the impairments added to, or impressed upon, the first transmission channel via the various channel impairment sources. The output of the first transmission channel is provided to a first receiver.

Each of the channel receivers (*A* - *D*) comprises a respective receiver equalizer *R(f)*, a slicer or decision device *BS*, a subtractor or differencer *D* and an adaptation algorithm *AA* implemented using a controller or other computing device.

Each of the respective receiver equalizers $R_1(f)$ to $R_4(f)$ has a transfer function that is optionally modified by a respective adaptation algorithm in response to an error signal. For example, receiver $R_1(f)$ of channel A has a transfer function that is adapted in response to a control signal CON_1 produced by an adaptation algorithm AA_1. The adaptation algorithm may be implemented using, for example, a computing or data processing device comprising, illustratively, a microprocessor, a memory, input/output circuitry, and support circuitry. Computer executable instructions stored within the memory and executed by the processor implement the steps necessary to effect the adaptation algorithm.

Each of the slicers or decision devices BS_1 through BS_4 receives an equalized signal from its respective receiver equalizer $R_1(f)$ through $R_4(f)$ and operates in a known manner to produce at its output a signal of the form $\hat{a}^{(x)}(n)$, where *x* represents the channel number. The output signal produced by the slicer *BS* should be substantially the same as the output signal produced by the encoder *E* at the transmitter. Differences between the actual signal produced by the bit slicer *BS* and the actual signal produced by the encoder *E* represent errors caused by, for example, channel impairments, such as previously discussed. Some of these errors may be reduced by adapting the operating parameters of the receiver equalizer *R(f)*. However, other errors (especially those caused by interchannel interferences) are preferably addressed using the pre-coder function of transmitters constructed according to the principles of the present invention.

In the exemplary embodiments discussed herein, the transmitters use

Carrierless Amplitude and Phase (CAP) modulation, though QAM or other encoding technology may be employed. Each transmitter has an independent data source generating, illustratively, 4 bits at every symbol interval. The encoder maps the 4 bits of data into complex symbols within a 16-point CAP/QAM transmitter. The encoded symbol stream is then passed through a transmit shaping filter $G(f)$ to the channel. The CAP shaping filter is implemented as a complex input, complex coefficient, real output FIR filters whose real part (in-phase) and imaginary part (quadrature) of the impulse response form a Hilbert pair. The shaping filter has a passband square-root raised cosine characteristics with an equivalent center frequency of, illustratively, 16 MHz. The transmitter has an equivalent symbol rate of, illustratively, 12.96 Mbaud/s. It is noted that these specific parameters are intended to illustrate a specific example of an embodiment of the invention. Those skilled in the art and informed by the present disclosure will be able to devise other examples.

In the embodiment of FIG. 4, information necessary in establishing the operating parameters of the pre-coders associated with each of the transmission channels is determined by adapting the pre-coder operating parameters and measuring, at a respective receiver, a quality of an encoded signal processed thereby. For example, by monitoring a bit error rate and/or other error indicia, a receiver may provide data to a transmitter suitable for determining pre-coder parameters such that the bit error rate (BER), symbol error rate and/or other error indicia may be favorably adapted. The pre-encoders are operationally modified by adapting the pre-encoded matrix or matrices used to implement the various equations discussed above.

In a preferred embodiment of the invention, the initial pre-coder operating parameters are determined entirely at the respective receivers. Specifically, FIG. 5 depicts a high level block diagram of the multiple channel transmission system of FIG. 4 further modified to include receiver side pre-coders. In one embodiment of the invention, the system of FIGS. 4 and 5 operate in a training mode as depicted with respect to FIG. 5, followed by a

normal operating mode as depicted by FIG. 4. The system 500 of FIG. 5 differs from the system 400 of FIG. 4 in that each of the receivers within the system 500 of FIG. 5 further comprises three respective pre-coders and summing means adapted to summing the output of the respective pre-coders and a received signal. In addition, the adaptation algorithms *AA* of the respective receivers are modified to enable to adaptation of pre-coder matrix or matrices for the receiver pre-coders such that in a training mode the receiver may itself rapidly determine at least an initial, if not optimal, pre-coder operating parameter set for the transmitter-side pre-coders.

Referring now to FIG. 5, each of the encoders E_1 through E_4 provides a predetermined training sequence of the form $a'^{(i)}(n)$ to its respective receiver via its respective channel. The predetermined training sequence is known to each of the respective receivers. It is noted that the receiver equalizers *R(f)* may also be trained. However, the training of receiver equalizers is beyond the scope of the present invention, since such receiver equalizer training depends entirely upon the particular implementation of the receiver, and since the teachings of the present invention may be successfully employed using many different receiver equalizer implementations. Referring to FIG. 5, at each receiver a substantially identical predetermined training sequence of the form $a'^{(i)}(n)$ is coupled to the receiver differencer *D*. The training signal transmitted from the respective transmitter through the respective channel is received by the receiver equalizer *R* and coupled to a receiver summing element *SR*. Additionally, each of the three pre-coder elements representing channel impairments caused by each of the three other channels provide respective output signals (in response to respective input training sequence or matrix values) which are also coupled to the receiver summing element *SR.* The output of the receiver summer *SR* is provided to a differencing element *D*, where it is compared to the known predetermined training sequence. Difference data *B* is coupled to the adaptation algorithm *AA,* which responsively adapts one or more of the pre-coder functions and/or the receiver function.